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A review of the e-learning resources on building physics for architects

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Abstract

This paper discusses about e-learning resources for supporting the implementation of sustainable environmental design (SED) in the architecture discipline. The research has identified from the literature that organisation of learning materials, visualisation of information and enabling interdisciplinary communication are the key factors of designing an effective e-learning tool for this task. The review found the available e-learning resources being very limited in number with respect to building physics. The EDUCATE Portal and Autodesk Sustainability Workshop website can be considered good examples of the e-learning tools reviewed in this paper.

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Keywords: e-learning resource/tool; architect; building physics; learning material organisation; information visualisation; collaborative learning

1. Introduction

The rising concern on sustainable development globally urges the building industry to deliver low energy and environmental buildings. This has led to an increasing demand on architects' ability to produce environmentally conscious and responsive designs [1,2,3,4]. However many architects stated that the education in the architectural discipline and their professional working experience are insufficient to facilitate them to adapt to the new role [5,6,7,8]. This paper reviews the available e-learning resources on building physics, which could be seen as an essential knowledge base in producing sound sustainable environmental design (SED), and identifies how the

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resources are suitable as e-learning tools for enhancing the understanding of architects about the performance of their designs, on which architects conventionally have low involvement [5,7,9,10].

1.1. E-learning – information and communication technology (ICT) in education

E-learning refers to learning and teaching using methods or materials offered by electronic technologies, of which the majority is information and communication technology (ICT) [11]. The most considerable changes in education by e-learning, as discussed in researches [11, 12, 13, 14], are in general on the following aspects: time and space flexibility, active control of the learning process by the learner, new forms of interactions with knowledge. In a properly designed e-learning experience, the learner is enabled to decide when, where and how he/she engages with the knowledge, while guidance and instructions are provided for assistance.

Such new form of learning is particularly beneficial for the disciplines, which have a strong relationship between the knowledge and its real-life applications [12]. E-learning has already proved its effectiveness in improving knowledge transfer in many disciplines, including medicine and engineering [2, 12]. Learning and practicing have always been essential for architecture education, and therefore e-learning is an important aspect to be studied to enhance the transfer of knowledge of building physics to the architects.

1.2. Background of the reviewed e-learning resources on building physics

Romiszowski defined in his research [15] four categories of e-learning resources depending on whether the resource focuses on individual or collaborative study, and whether the learning is through real-time interaction with the resource, or conducted not during accessing the resource but by using the materials obtained from the resource.

As E-learning tools for building physics are a rather new thing, the current study looked for the existing e-learning resources on building physics using Google and also from websites given as reference in relevant literature. Although this is a rather *ad-hoc* practice, it was considered that due to the nature of the tools, and that professionals are likely to use this means to find them; this could have been a good approach for the first exploration of their availability. Only four web-based e-learning resources were found in this search that contain a systematically arranged collection of educational materials. They are EDUCATE Portal (by EDUCATE project), Green Building Educator's Toolkit (GBET) (by National Housing Endowment and NAHB research center.), Building Science Corporation's (BSC) website (by Building Science Corporation), and Autodesk Sustainability Workshop (ASW) website (by members of Autodesk). It is likely that there are some tools available on the Internet or the networks of other corporations. However, as the search that we performed took us to this four, we have considered that this is a consequence of these four being the most popular/accessible at the moment and therefore worth reviewing.

EDUCATE Portal is an online platform offering learning materials on the principles, methodologies, and building cases on SED [2]. The portal is developed in the EDUCATE project, run between 2009 and 2012 to emphasise SED across Europe. It allows both individual and collaborative study through direct interaction.

GBET is a bibliography providing links to educational materials on the design of green residential buildings and systems [16]. The toolkit was created in 2010 to support university programs in residential construction management in the USA. Green design educators can distribute the toolkit to their students.

BSC website was built up for sharing knowledge about building physics and practical issues of SED [17]. The website contains a rich collection of articles which are suitable for individual learning. Participating in discussions on the website requires relatively high expertise on building physics.

ASW website offers online educational materials, featured in explanatory videos, on the principles and methodologies of applying SED [18]. The learners and educators can share knowledge in the community block.

The above four e-learning resources contain a variety of materials and cover various learning modes, and will be evaluated in this paper using the preferences identified in the literature review.

2. Literature review

The literature review has been done to summarise the approaches proposed by the architecture curriculum in Europe and in the USA to improve the understanding of SED by the architects and point out their desired

preferences on the e-learning tools. The current trend on education of environmental design in the architecture discipline will be described first, followed by a review of the main factors that determine the effectiveness of an e-learning tool on enhancing the learning experience, and then the preferences will be concluded.

2.1. Education of environmental design in the architecture discipline

The investigation on teaching of SED in the architecture courses in the EDUCATE project found that apart from the countries which has long been appreciating the importance of sustainability in the academic qualification in architecture, the priority of environmentally responsive design is also increasing in other European countries. The introduction and training about sustainable design has been included in more architecture programs either in the design studios or as separate modules [2]. In the USA, following the National Architectural Accreditation Board (NAAB)'s higher requirement on architecture courses teaching sustainable design [3], a growing emphasis can be observed across the states, and the U.S. Department of Energy is developing a roadmap to strategically enhance sustainable design in architectural education [19].

The proposed approaches on improving the implementation of SED, though formulated under different contexts over the countries mentioned above, show a commonality on indicating the importance of the following two aspects:

- Practical SED experience
- Interdisciplinary collaboration with other disciplines specialised in theories and methodologies of achieving sustainability

A few architecture programs [1,4,20] restructured with a key focus on the two aspects have already seen a progress on the architecture students' competence on delivering sustainable designs. The two studio courses discussed in [1] and [4] applied knowledge transfer/sharing from various disciplines from the beginning of the courses and this was found to effectively shift the students' perception of sustainable design from avoiding non-sustainable to creating a built environment that benefits all in the community. The experimental collaboration between architecture and engineering students in [20] found that exchanging knowledge about design and sustainability in the individual disciplines help them better understand the languages spoken by the other.

2.2. Effectiveness of enhancing learning experience by e-learning and architects' preferences on e-learning tools

As indicated in the research by Brown and Voltz [11], the design of an e-learning tool could considerably affect its effectiveness in enhancing the learning experience. Interaction with well-arranged learning materials helps drive an active learning process [11, 13], and proper use of multimedia enhances the efficiency of understanding the delivered knowledge [13].

The learning materials need to reflect the structure of knowledge and the e-learning tool should provide a clear mapping to the materials [11]. In this way the tool allows the learner to more easily identify the perspective pathway of study based on the completed study, and therefore motivate the active learning process. Linking the materials on principles with practical issues can also stimulate learning and improve the richness of understanding about the knowledge. This is consistent with architects' desired functions on environmental design tools, which are well-organised interactions and showing the relationship between principles and the design [5, 21, 22].

The use of multimedia in the e-learning tools, especially for visualising information, is particularly beneficial for architects, as architects basically learn and work with visual materials [9]. The CAL-Visual system described in the research by Bouchlaghem et al. [23] is used for teaching of technical information of constructions with photos taken on real sites. This was appreciated by the students as a key motivation for them to conduct self-learning with the system. Rudy and Hauck [24] also discussed how the visualization of the theoretical model of a structural system helps the students to analyze the structure of real constructions. It can therefore be expected that visualisation of building physics knowledge can also improve the effectiveness of learning. In addition, according to the dual coding theory [25,26], information presented visually as well as verbally is stored in two segments of people's long-term memory and can recall each other and therefore allow the learner to retrieve knowledge more effectively. In terms of the format of the visual material, static graphics, animations and videos can be managed in e-learning tools to enrich

the learning activities and control the flow of information. However inappropriate use of graphical material can also lead to overloading of information and distract the learner [15]. For instance using a complex building geometry to show the parameters influencing daylight distribution could hinder the explanation of principles. Based on the above reviews, architects' preferences on e-learning tools can be concluded in Table 1.

Table 1. Preferences on e-learning tools for the architects to improve their understanding on building physics

Organisation of learning materials	Use of multimedia	Collaborative learning
Clear mapping according to the structure of knowledge	Visualisation of scientific and technical information	Virtual community for interdisciplinary communication
Explicit link between principles and practical applications	Variety in the format of the visual materials	
	No overloading of information	

3. Evaluation of the available e-learning resources on building physics

The contents and structure of the four e-learning resources being reviewed will be described in section 3.1, and they will be evaluated and ranked in section 3.2 according to the preferences presented in Table 1.

3.1. Contents and structure of the four e-learning resources

EDUCATE Portal is built upon a knowledge triangle of principles, tools for analysis, and applications and case studies, as shown on Fig. 1 (a). A complete set of topics of SED, including climate and comfort, heating cooling and ventilation, lighting, acoustics, urban quality, ecological footprint, resources and waste management, are listed under each sector of the knowledge triangle. The portal overall uses a rich collection of static graphics. The portal used to have four domains to divide the type of users (i.e. student, instructor, professional, and public), however this function has been deactivated after the EDUCATE project [2].

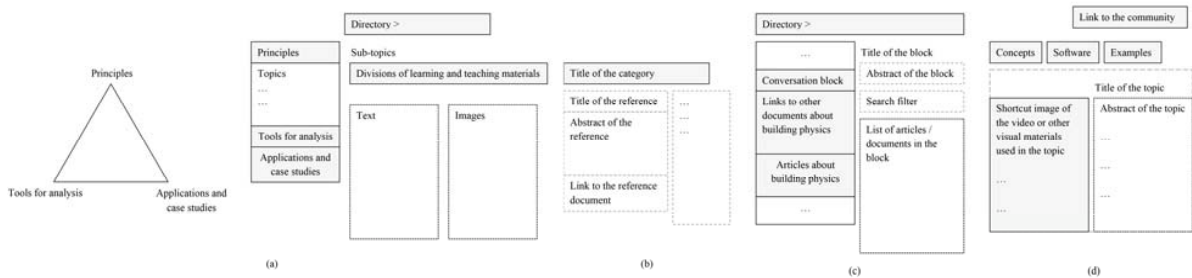


Fig. 1. Layout of (a) EDUCATE Portal; (b) GBET; (c) BSC website; (d) ASW website

GBET (Fig. 1 (b)) is a downloadable document. References given in GBET are divided into six categories: curriculum-related, theory-related, technology-related, standards-related, application-related and environmental-related [14]. In each category the references are ordered alphabetically. Only parts of the SED topics are covered, with an apparent focus on heating, cooling and ventilation, with one reference on visual comfort and no acoustics. GBET is text-based, and does not provide platform for communication.

The BSC website (Fig. 1 (c)) contains two categories of articles: short introductions, and in-depth discussion on specific topics [15]. A rich collection of other documents including building case studies, design guidelines and research publications can also be linked from the website. The articles cover air, heat and moisture flow in buildings, and again materials on visual comfort and acoustics are limited. Text forms the majority of the materials on the website, with a minor use of graphics to assist explanation. The conversation block allows the visitors to post comments, though participation in the discussion requires in-depth knowledge.

The ASW website (Fig. 1 (d)) shares a similar structure to EDUCATE Portal. It divides the materials into: concepts of SED, software for analysis and example design projects [16]. Each block contains a series of topics in which sub-topics can be accessed. The topics include climate and site, building energy and systems, passive design, lighting, and building water resources. The website incorporates text with static graphics and a substantial number of videos. The users can post comments under each topic and the website also includes a virtual community where the users can raise other topics for discussion.

3.2. Ranking of the e-learning resources as effective e-learning tools on building physics for architects

In terms of the organisation of learning materials, structure of the contents are clear on both EDUCATE portal and the ASW website, and the materials are arranged following the principle, methodological and practical division of the knowledge. The users can also easily recognize links between materials on the three divisions. The references in each category of GBET are only arranged alphabetically and the user can not see the structure of knowledge of the materials. There is also no link between the materials about principles and practical issues on GBET. The BSC website allows the users to filter the articles by climatic zones, but the structure of knowledge and links between principles and applications are also missing.

On the use of multimedia, the ASW website is the only one using video as the main format of visual materials, which gives it a higher rank than EDUCATE Portal, which is equally rich in static graphics for presenting information. Explanatory images can only be found on a small proportion of articles on the BSC website, and GBET contains no visual material. No overloading of information is found on any of the e-learning resources.

The virtual community of the ASW website is open to learners on all levels and enables interdisciplinary communication. The user domains of EDUCATE Portal performed well during the EDUCATE project, but is no longer running. The conversation block of the BSC website is managed strictly and the contents posted are more reliably than the others, but is not suitable for collaborative learning by non-experts. Communication cannot be made within GBET. The ranks of the four e-learning resources are summarized in Table 2.

Table 2. Ranks of the four reviewed e-learning resources on their effectiveness of enhancing learning experience

Clear mapping according to the structure of knowledge	Explicit link between principles and practical applications	Visualisation of scientific and technical information	Variety in the format of the visual materials	No overloading of information	Virtual community for interdisciplinary communication
EDUCATE, ASW	EDUCATE, ASW	EDUCATE, ASW	ASW	N/A	ASW
GBET, BSC	GBET, BSC	BSC	EDUCATE		EDUCATE
		GBET	BSC		BSC
			GBET		GBET

The above ranks are purely on how well the educational materials are used to enhance the effectiveness of the learning experience, while the quality of the materials is not taken into account. Therefore the ranks or the criteria may not be used for a complete evaluation of e-learning resources/tools, but are provided to exemplify how an e-learning tool for architects to learn building physics can be designed.

4. Conclusion

The final conclusion after this study is that the available e-learning resources are very limited being reduced to a number smaller than a dozen, but that architects could benefit from e-learning tools to improve their competence on

SED especially if the tools are designed following the preferences that we have found in the literature. The learning materials should be mapped clearly according to the structure of knowledge. Explicit link between principles and applications needs to be displayed. Visualisation of scientific and technical information in various formats needs to be applied without overloading of information, and interdisciplinary communication needs to be enabled. The ASW website and EDUCATE Portal have the highest overall rank according to the preferences, while the BSC website and GBET are weaker in arranging the learning materials and harness graphics for knowledge transfer. This shows that the development of e-learning tools for architects on building physics or other aspects of SED is a research field to be explored with grand potential if done in a proper way.

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